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Final report on NASA Project No. NAG4-103: INSTRUCTION QUALITY, ACCESS, RELEVANCE, AND RETENTION IN SCIENCE AND ENGINEERING

Focus: Interactive Labs of the Future

by

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In engineering and science, prediction and experiment go hand in hand. The **Interactive Labs of the Future** focus outlined herein is intended to address in a central fashion the overall theme of instruction quality, access, relevance, and retention, expanding this thrust to the important experimental side of higher education. Substantial real synergies are sought in this focus via the complementary integration of computer technology in experimental instruction topics (the main topic to be addressed as part of this proposed effort will be experimental instruction in **Aeronautical** Engineering). By combining high quality multimedia descriptions of the relations governing a physical phenomenon, with computer simulations and actual hands-on experiments, one can significantly enhance the impact and efficiency of laboratory experiences.

The support from NASA was used for the planning and development of truly innovative laboratory and instrumentation courseware modules which can serve both the NASA community and higher education in this extremely important area. The general philosophy of the **Interactive Labs of the Future** has been to develop students' experimental, computational and analytical skills in a coherent and complementary fashion via an advanced interactive environment. Central in the proposed approach is the novel, innovative, and synergistic investigation of the use of computer based techniques that exploit the unique characteristics of laboratory and instrumentation instruction and move it to a powerful new medium. These techniques include:

1. the use of the computer for digital data acquisition and control of experiments via a LabVIEW software interface,
2. readily and continuously simulating behavior (either of an instrument or physical phenomenon) by both students and instructors using the LabVIEW Virtual Instrument environment,
3. central use of powerful computer mathematics capability to engage students in the derivation and manipulation of the relationships being developed.

As part of this effort, several LabVIEW components to the laboratory courseware modules which are relevant to the mission of NASA were developed. These labs are:

1. Interactive Digital Signal Processing and Time Series Analysis
2. Interactive Vibrations Lab
3. Interactive Solid Mechanics Lab
4. Interactive Aerodynamics Lab
5. Interactive Jet Impact Lab
6. Interactive Heat Transfer Lab

All of these LabVIEW based courseware models are being BETA tested in our Mechanical and Aeronautical labs during the fall 96 and spring 97 semesters.

The following figures present LabVIEW based GUIs for the first 2 labs. Figure 1 shows the LabVIEW based GUI for the Interactive Digital Signal Processing and Time Series Analysis lab. A overview of this lab is included in the Appendix to give the reader a sense of what constitutes a complete **Interactive Digital Signal Processing and Time Series Analysis Laboratory**.

Figure 2 shows the LabVIEW based GUI for the Interactive Vibrations Lab. A overview of this lab is included in the Appendix to give the reader a sense of what constitutes a complete **Interactive Vibrations Laboratory**.

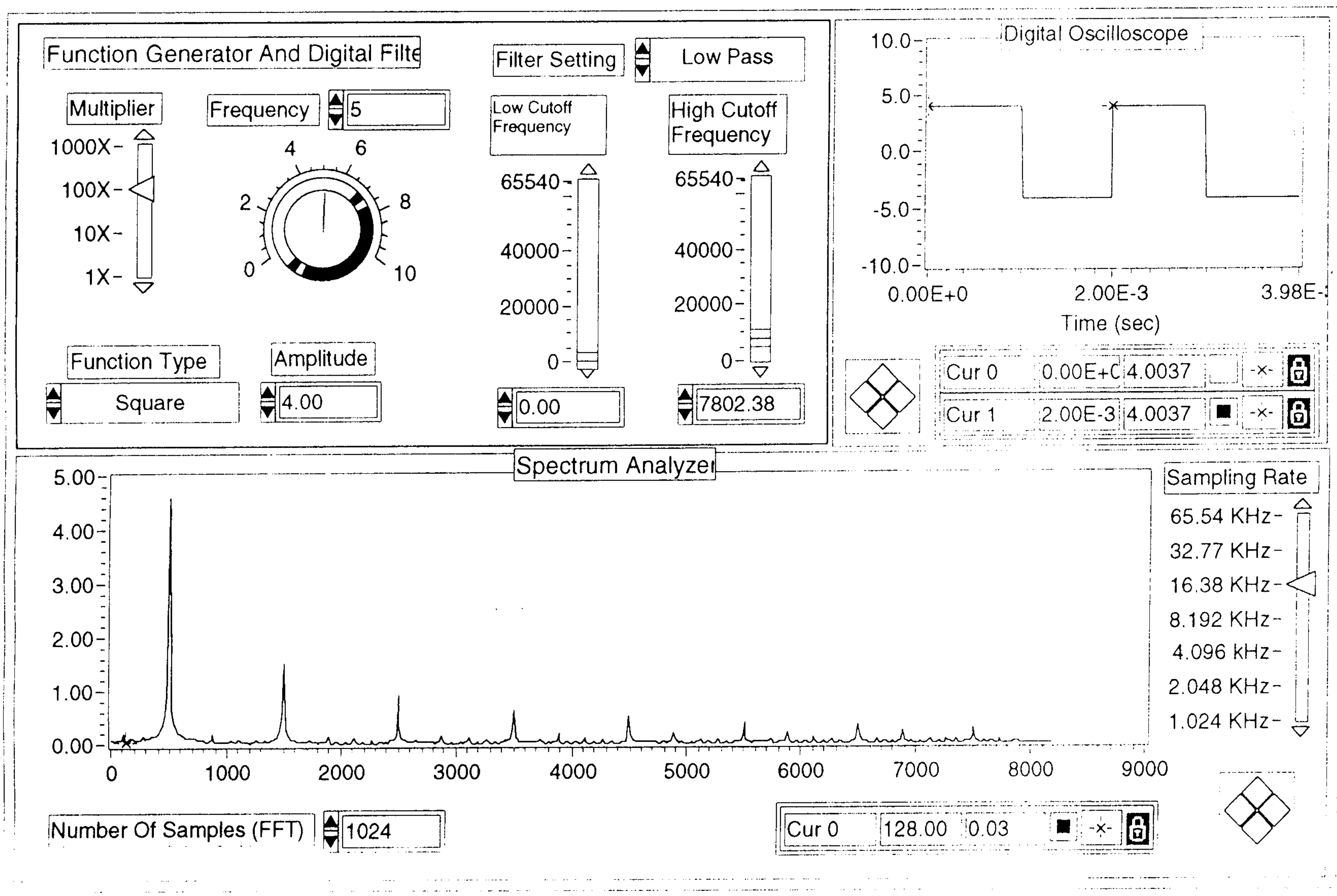

Figure 1 shows the LabVIEW based GUI for the Interactive Digital Signal Processing and Time Series Analysis lab.

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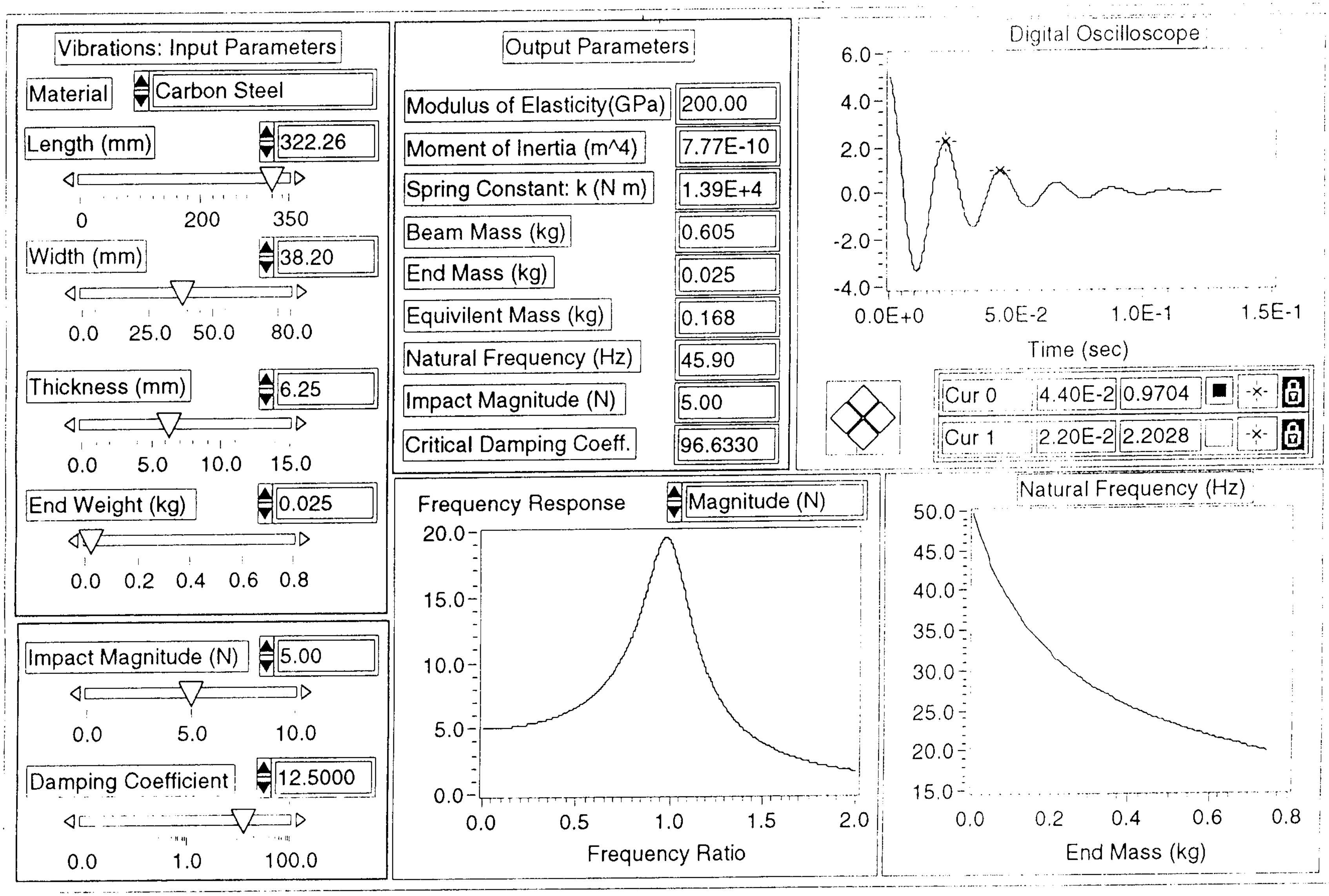

Figure 2 shows the LabVIEW based GUI for the Interactive Vibrations Lab.

APPENDIX

Outline for Interactive Digital Signal Processing and Time Series Analysis

- The first thing we need to do is provide motivation for the student. Why is digital data acquisition and time series analysis important? In what types of problems is Fourier Analysis useful? What happens if data is sampled to slowly? To answer this question we will show TV commercials with the car tires apparently turning backwards. This is a direct result of aliasing since the videos were filmed at 30 frames per second. Examples demonstrating quantization and clipping, will be included. We can weave in how music CDs are made. We will introduce the students to the concept of spectra and filtering utilizing LabVIEW. Practical examples which the students can relate to such as spectra of various music pieces will be included. Frequency response characteristics of various devices (the human ear for example) will be presented. This serves as a useful way to introduce the concept of filtering and general signal conditioning. Other examples more specifically related to Mechanical and Aerospace Engineering can be easily included as well.

- The second step is to provide simulations of various related material for the students to interactively work with. We could take some analog recorded music and sample it to slowly. These undersampled pieces could then be replayed and differences noted. Spectra of various signals could be computed using LabVIEW. These could be music pieces, hot-wire and accelerometer signals, or sine, square and triangle waves. The point here is to develop the students intuition for the various processes.

- The third step will require the students to derive via MAPLE the equations for aliasing as well as the Fourier components of sine, square and triangle waves. They would also be required to derive the system transfer function for the low pass filter because of its use for anti-aliasing.

- The fourth step involves repeating the simulations again. At this point however, the students now have knowledge of the equations. The students should vary interactively the various parameters in the equations. This could involve changing sampling rates, amplitudes and frequencies of the various waves etc. In fact this could show the student the power of simulations for solving problems numerically which are not tractable analytically. Here again the students would utilize LabVIEW to compute Fourier components and spectra via FFT of various signals. This can clearly show the student the need for the computer for computing the spectrum (via FFT) of real world signals. That is signals for which the Fourier Transform is not known such as hot-wire signals from turbulent flows, accelerometer signals from vibrating systems, etc.

- The fifth step will involve a pre-lab. A review can be presented here for the students which will address for example, what parameters are to be varied?

A self-test to insure students readiness to perform the actual lab would be implemented at this point.

- The sixth step will be to run the experiment interactively. This will involve digital data acquisition utilizing a LabVIEW environment. Students will be introduced to LabVIEW via training sessions which will be part of the overall lab course. This will provide the students with a powerful tool for running all of the labs and for some post processing of the experimental data. The students will be required to vary the various parameters as much as is feasible experimentally. The power of simulations for varying parameters compared to trying to vary them experimentally will be emphasised at this point. This is a good point to also articulate the limitations of analytical and numerical approaches. What happens when the signals become chaotic for example? Analytical techniques are extremely limited in this case and numerical techniques somewhat limited. Hence, this will reinforce in the students mind the need for experiments. The point is to convince the student of the need for the use of analytical, numerical and experimental techniques in a complementary and coherent fashion.

Note: Each of the afore-mentioned items could be individual icons on a tool bar. The first one for example could be labeled Introduction and so on.

Outline for Interactive Vibrations Lab

- The first thing we need to do is provide motivation for the student. Why study vibrations? What practical problems are influenced by vibration? This will be handled by having several video examples of actual NASA footage of vibration problems on aircraft and space structures. Other more general examples can be easily included as well.

- The second step is to provide simulations of the particular structure to be examined in the lab (at Clarkson we have a cantilever beam and a simple spring, mass, damper system). Demonstrate via simulations, for both the impulse response and the response to sinusoidal excitation for various frequencies, the frequency response function. Show what happens when the structure is excited at or near its natural frequency. Reference the corresponding region from $H(\omega)$ simultaneously.

- The third step will require the students to derive via MAPLE the governing differential equations for the simple linear spring, mass damper system. This should be done both in physical and Fourier space. The equations should be cast in a form which will allow the students to see the effect of varying the various parameters on the system (e.g., mass, damping, spring constant). They then should also derive $H(\omega)$ from the governing equation.

- The fourth step involves repeating the simulations again. At this point however, the students now have knowledge of the equations. The students should vary interactively the various parameters in the equations. This could involve changing spring constants, length of the cantilever beam and damping. Large geometric changes could be implemented here as well. In fact this could show the student the power of simulations for solving problems numerically which are not tractable analytically. An interactive video window should be included here so that real world examples showing the effect of varying the parameters can be presented.

- The fifth step will involve a pre-lab. A review can be presented here for the students which will address for example, what parameters are to be varied or what are the parameter ranges which may cause saftey concerns? A self-test to insure students readiness to perform the actual lab would be implemented at this point.

- The sixth step will be to run the experiment interactively. This will involve digitial data acquisition and control utilizing a LABVIEW environment. Students will be introduced to LABVIEW via training sessions which will be part of the overall lab course. This will provide the students with a powerful tool for running all of the labs and for some post processing of the experimental data. The students will be required to vary the various parameters governing the system as much as is feasible experimentally. The power of simulations for varying parameters compared to trying to vary them experimentally will be emphasised at this point. This is a good point to also articulate the limitations of analytical and numerical approaches. What happens when the system becomes highly nonlinear for example? Analalytical techniques are extremely limited in this case and numerical techniques somewhat limited. Hence, this will reinforce in the students mind the need for experiments. The point is to convince the student of the need for the use of analytical, numerical and experimental techniques in a complementary and coherent fashion.

Note: Each of the afore-mentioned items could be individual icons on a tool bar. The first one for example could be labeled Introduction and so on.